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The relationship between engineering bachelor qualifications and occupational status in Australia

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ABSTRACT

Internationally, the importance of science, technology, engineering and mathematics (STEM) for innovation and competition drives concerns about the adequacy of national STEM workforces. Data from the UK, USA and Australia suggest that, even immediately post-graduation, a significant proportion of engineering bachelor graduates do not work in engineering roles. Using the 2011 Australian census data, we present an investigation into the relationship between educational qualifications and occupational status of Australian engineering bachelor graduates, and how this status varies specifically with graduate age. We consider the implications of these findings and present recommendations for the recruitment and education of Australian engineering undergraduates. We conclude that engineering students would be better informed about, and equipped for, the world of post-graduation work if they were exposed to the likely options for their career trajectory. Likewise, secondary school students and others considering engineering undergraduate study would be more honestly advised if they were informed about the full range of career possibilities for engineering graduates and the probability that they are just as likely to work out of engineering as in it.

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STEM; engineering education, Australian census; educational qualifications; occupational outcomes

1. Introduction

1.1. The international STEM workforce pipeline

Internationally, the importance of science, technology, engineering and mathematics (STEM) for innovation and competition drives concerns about the adequacy of national STEM workforces (Anlezark et al. 2008; Carnevale, Smith, and Melton 2011; Mellors-Bourne, Connor, and Jackson 2011). In the USA and UK, it has been observed that there are now more STEM graduates than there are STEM jobs available (Charette 2013; Holt, Johnson, and Harrison 2011); yet, those, and other, countries report perceived shortages of STEM-skilled graduates (Atkinson and Pennington 2012; Healy, Mavromaras, and Zhu 2013; Rothwell 2013). There appears to be a disconnection between the numbers of students completing STEM discipline degrees and the number of people working in STEM occupations.

At least some of the apparent mismatch is probably due to confusion with definitions of what constitutes STEM employment (Langdon et al. 2011; Mellors-Bourne, Connor, and Jackson 2011; Rothwell 2013). Internationally, what is considered a STEM qualification and/or occupation is likely to vary between, and even within, countries. One Australian definition of STEM qualifications/occupations is provided by the Australian Council of Learned Academies (ACOLA)

based on Australian Standard Classification of Education (ASCED) codes:

- Natural and physical sciences (ASCED code 01);
- Information technology (IT) (ASCED code 02); and
- Engineering and related technologies (ERT) (ASCED code 03) (Healy, Mavromaras, and Zhu 2013).

Fully expanded to narrow fields of education, the ASCED contains codes for 120 areas of study/occupations. Table 1 provides the broad field of education codes included in the ACOLA STEM occupation definition.

In an analysis of the US STEM workforce, Carnevale, Smith, and Melton (2011) found that, 10 years post-graduation, 46% of workers with STEM bachelor degrees had left the field. Charette (2013) reported on the US Department of Commerce STEM workforce data that indicated 11.4 million (or about 75%) of the approximately 15 million US residents with a STEM bachelor's degree did not work in a STEM occupation. Using the UK Labour Force Survey data from 2004 to 2010 for 163,218 people, Greenwood, Harrison, and Vignoles (2011) observed that, of the 8944 people with undergraduate STEM degrees, only 3986 (about 45%) were employed in a STEM occupation. Using a range of UK

Table 1. ASCED broad fields of education included in ACOLA STEM definition.

Mathematical sciences	Process and resources engineering
Physics and astronomy	Automotive engineering and technology
Chemical sciences	Mechanical and industrial engineering and technology
Earth sciences	Civil engineering
Biological sciences	Geomatic engineering
Other natural and physical sciences	Electrical and electronic engineering and technology
Computer science	Aerospace engineering and technology
Information systems	Maritime engineering and technology
Other information technology	Other engineering and related technologies
Manufacturing engineering and technology	

workforce statistics, Holt, Johnson, and Harrison (2011) observed that, prior to 2010, the proportion of the workforce with a STEM degree was lower than the proportion of STEM jobs (for example, in 2004, about 6.3% compared to 7.5%). However, by 2010, for the first time, there were more holders of STEM degrees than STEM jobs – about 8.4% compared to 8.3%, respectively. Based on the same sources, Holt, Johnson, and Harrison (2011) noted that three and half years post-graduation, 28% of STEM graduates were in a non-STEM occupation. Drawing on EngineeringUK (a collaboration between UK engineering employers and professional bodies) sector data, Lyons (2011) noted that, ‘50% of male STEM graduates and 70% female STEM graduates do not, currently, work in the STEM sector’ (4). Specifically for engineering, using the US data tracking approximately 9000 bachelor graduates from 1992 to 1993, Choy and Bradburn (2008) found that, 10 years post-graduation, only about half (48.4%) of engineering majors were still working in a related field. Based on 2001 and 2006 Australian census data, counting those between 25 and 55 years of age with a bachelor’s degree or higher in engineering, and considering Australian- and foreign-born graduates separately, Trevelyan and Tilli (2010) found that overall, the percentage of graduates not working in engineering-related jobs was 53.4% in 2001 and 47.3% in 2006.

Allowing for differences in definitions of STEM employment, it is clear that many STEM graduates do not persist in the STEM workforce over the longer term. The stock-and-flow of STEM workers is often referred to as the ‘STEM pipeline’ and the metaphor is extended to the ‘leaky pipeline’ in describing the significant reduction that occurs over time in the proportion of STEM graduates working in STEM occupations. Many reasons for, and locations of, the ‘leaks’ in the pipeline have been proposed, but there is evidence that the ‘losses’ start early, including secondary school students who study STEM subjects not following through to STEM studies in higher education, and particularly for those students studying a STEM discipline at university not pursuing a STEM career. Charette (2013) reported on a US

National Science Foundation survey of STEM bachelor and master graduates 12–24 months after graduation that found 20% were already working in a non-STEM field. A STEM master’s degree indicates a level of commitment to the discipline area via further study, so based on the US bachelor-level-only completions, Carnevale, Smith, and Melton (2011) found 43% of recent STEM graduates were not working in STEM occupations. In the UK, Holt, Johnson, and Harrison (2011) reported that almost 40% of STEM graduates were working in non-STEM occupations after graduation, with the fraction at 26% for engineering graduates.

In Australia, using data from the Longitudinal Survey of Australian Youth to analyse the STEM pipeline of students taking STEM subjects in school, those commencing post-school STEM studies, and those working in STEM careers, Anlezark et al. (2008) found that, while about half of all students who studied two or more STEM subjects in year 12 went on to post-school STEM studies, only about one-third of those completing post-school STEM studies went on to a STEM career. They concluded that, ‘The greatest leakage from STEM is the pathway from commencing post-school STEM study into a STEM occupation.’ (5). Looking specifically at Australian engineering graduates, an admittedly small survey of recent engineering graduates by the Department of Education Employment and Workplace Relations (2009) found 74.4% of engineering graduates were employed in engineering occupations nine months after graduation, including 2.9% of graduates working overseas as an engineer.

1.2. Where do STEM graduates go?

If a high proportion of STEM graduates do not remain in STEM occupations, and in particular a significant number of graduates never enter the STEM workforce, then where do they go and why? The US Department of Commerce observed that, ‘STEM degree holders enjoy higher earnings, regardless of whether they work in STEM or non-STEM occupations’ (Langdon et al. 2011, 1) and, ‘... in addition to STEM jobs, STEM degrees also open the door to many other career opportunities’ (Langdon et al. 2011, 4). In the study by Carnevale, Smith, and Melton (2011), three factors driving the US STEM graduates away from STEM occupations were identified:

- (1) the core knowledge, skills and abilities associated with STEM also exist in an increasing share of highly paid and prestigious non-STEM occupations;
- (2) many potential STEM workers never work in, or leave, STEM occupations because they have interests and values more compatible with other careers; and
- (3) while STEM earnings are high relative to many occupations, STEM competencies provide

access to superior earnings and alternative career paths in management, professional and health care occupations.

In relation to point three, they found that, by mid-career, the US STEM workers with graduate degrees made about \$50,000 less than health care workers with a graduate degree.

Bhattacharjee (2009) reported on a separate study into the US STEM pipeline that found an increase in the proportion of all STEM graduates in STEM jobs 10 years post-graduation across cohorts of graduates from 1977 to 1993, but a decrease for the highest performing STEM graduates, as measured by academic results. For the cohort graduating in 1977, graduates in the top academic quintile were 10% more likely to be still in a STEM job 10 years later (about 45%) than the average of all STEM graduates. In the 1993 cohort, the top academic quintile of STEM graduates was less likely to still be in a STEM job 10 years later (about 43%) than the average of all graduates. That was viewed as evidence of the widely held perception that the 'best' STEM graduates were being drawn into careers in finance and management due to the higher salaries on offer. In his report noted above, Lyons (2011) found that this perception extends to the UK, with STEM employers in the London region, suggesting that many of the 'best' STEM graduates are 'poached' to the non-STEM sector by higher salaries. He found that, 'the skills that STEM graduates possess are fully transferable, usually with a solid understanding of mathematics supporting a strong practical skills base result in many working outside of STEM'. (Lyons 2011, 4). Lyons (2011) further observed that 28% of the UK engineering graduates enter finance and business – the same rate as all other graduates. Based on interviews with a large number of UK STEM graduates and employers, Mellors-Bourne, Connor, and Jackson (2011) observed that graduate career paths are often individual and complex. They offer a range of reasons why STEM graduates pursued non-STEM careers, including other fields are seen to be of more interest; expected earnings are an important factor; major non-STEM employers with established graduate schemes were attractive to 'undecided' graduates; and some STEM employers felt that the STEM sector had a less attractive image than some other sectors.

Providing an Australian perspective, Healy, Mavromaras, and Zhu (2013) analysed the 2011 national census data to understand where STEM graduates find employment. Noting that there is no one-to-one correspondence between qualifications and occupations, they found that, at the broad occupational classification level, 10 classifications accounted for about 80% of all STEM graduates. The first-, second- and fifth-ranked occupational areas were clearly STEM occupations and accounted for 47% of graduates. However, the other seven broad occupational categories were not

specifically STEM related and included about one-third of all Australian STEM graduates. As noted above, a survey by the Department of Education Employment and Workplace Relations (2009) found 74.4% of recent engineering graduates were employed in engineering occupations nine months after graduation. This implies that even shortly post-graduation, about one-quarter of engineering graduates were not employed in an engineering occupation. Although, via their survey, they concluded that, 'The majority of respondents employed in occupations other than engineering in Australia in 2008 were working in highly skilled occupations' (Department of Education Employment and Workplace Relations 2009, 3). Using the same national data-set as Healy, Mavromaras, and Zhu (2013), we present an investigation into the occupational status of Australian engineering bachelor graduates, and how this status varies with graduate age. We consider the implications of these findings and present recommendations for the recruitment and education of Australian engineering undergraduates.

2. Method

Using the Australian Bureau of Statistics Census online TableBuilder service (<http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder?opendocument&navpos=240>), a tabulation of Non-School Qualification: Field of Study – ERT, Non-School Qualification: Level of Study – Bachelor Degree Level and Age: Age in Five-year Groups, vs. Occupation – 4 Digit-Level was produced for the 2011 Australian census data. It is important to note that the census ERT qualifications data include 80 separate qualification areas. However, at the bachelor qualification level (the level of interest here), only 10 qualifications not specifically named as 'engineering' contain any graduates. In total, these account for only 8.3% of bachelor graduates in the ERT qualifications area and the two largest qualification titles ('Surveying' and 'Communication Technologies' – accounting for 4.6% of bachelor graduates) almost certainly contain some people who would now graduate from engineering degree programmes, i.e. geomatic engineering. It is important to note that the census bachelor's degree-level qualification data do not distinguish between engineering technologist bachelor qualifications (typically three years, full-time equivalent duration) and professional engineer bachelor qualifications (including combined degree programmes, typically four years or more in duration). However, statistics compiled by the Australian engineering professional body (Engineers Australia) (Kaspura 2014) indicate that engineering technologist graduates are a relatively small proportion of all engineering bachelor graduates – 7.4% in 2011. It is difficult to estimate accurately, but a proportion of the students enrolled in three-year bachelor engineering programmes will articulate

on to professional engineering studies, and except in a limited number of particular State jurisdictions and/or particular industries, there is no practical restriction on three-year-qualified bachelor engineering graduates practising in any engineering occupation in Australia.

The census data-set cross-tabulates those respondents indicating a bachelor-level engineering qualification against 477 occupational classifications. These occupational classifications clearly identify 11 groups related to professional engineering, those not working and those whose occupation cannot be classified. The remaining 463 non-professional engineering occupational classifications were clustered into 11 broad groups. For all respondents reporting a bachelor-level engineering qualification, the proportions of the consolidated engineering occupations and the 13 other occupational groups were graphed for comparison. For all respondents reporting a bachelor-level engineering qualification, and grouped into five-year age ranges, the proportions of the three broad employment status categories of 'working as a professional engineer', 'otherwise employed' and 'not working' were graphed, along with the total number of respondents in each five-year age range. These results were compared to similar data in the related literature and to other national graduate data-sets, including Australian higher education course completions data and the Graduate Destinations 2011 report compiled by Graduate Careers Australia. The results obtained and their implications are discussed.

3. Results

In the 2011 Australian census data, 200,356 respondents reported a bachelor-level engineering qualification. Table 2 presents the census 4 digit-level occupational classifications used to identify respondents currently working in a professional engineering role. Figure 1 presents the proportions of respondents reporting a bachelor-level engineering qualification, grouped by consolidated engineering occupations and 13 other broad occupational groups. Figure 2 presents the proportions of respondents reporting a bachelor-level engineering qualification, in five-year age ranges, grouped into the broad employment status categories of 'working as a professional engineer', 'otherwise employed' and 'not working'. Figure 2 is designed to permit direct visual

Table 2. Census 4 digit-level occupational classifications relating to professional engineering.

Chemical and materials engineers	Civil engineering professionals
Electrical engineers	Electronics engineers
Industrial, mechanical and production engineers	Mining engineers
Other engineering professionals	Engineering managers
Engineering professionals (not further defined)	ICT support and test engineers
Telecommunications engineering professionals	

comparison of the proportions of employment status between the age range groups. It also includes the total number of respondents in each age range, so that the displayed percentages can be converted to approximate absolute numbers via multiplication.

4. Discussion

4.1. Data limitations and triangulation

There are a number of limitations in the use of the Australian census data here. As with the Australian population that it represents, there is not a one-to-one correspondence between the recorded educational qualifications and occupations of respondents (Healy, Mavromaras, and Zhu 2013). While the identification of relevant qualifications is relatively straightforward (bachelor's degree level in ERT), choices have to be made about which occupational classifications to include in 'the professional engineering workforce'. Having made definite choices regarding educational and occupational classifications, the quality of the data thus obtained is influenced both by the response accuracy of those completing the census and the choices made by those coding those responses into the census database. Trevelyan and Tilli (2010) used the recorded country of birth to highlight differing occupational outcomes for Australian- and foreign-born holders of engineering qualifications. The data used here include both Australian- and foreign-born persons with both Australian and international engineering bachelor-level qualifications; however, that is not unrealistic, as it represents the Australian engineering workforce at the time of the census.

The Australian census only asks respondents for their highest qualification. A respondent with an engineering bachelor qualification who has completed a graduate diploma (i.e. in education), a master-level qualification (i.e. a master of business administration – common in engineering) or any other non-engineering graduate qualification is not recorded as having an engineering qualification (Healy, Mavromaras, and Zhu 2013; Trevelyan and Tilli 2010). This result systematically under-reports the number of people in Australia holding engineering bachelor qualifications, and hence also causes the inferred proportion of engineering bachelor holders working in a non-engineering occupation to be underestimated. In the data for Figure 2, very small numbers of engineering bachelor graduates were recorded in the age range 15–19 years and above 90 years. However, reported census data are subject to small random adjustments to avoid the possibility of categories with very small numbers of respondents, possibly leading to the re-identification of individual respondents. As such, these very small results were excluded here for clarity.

It is difficult to directly confirm the results from the census data above. Regarding Figure 1, as noted above, in a longitudinal investigation of the US bachelor

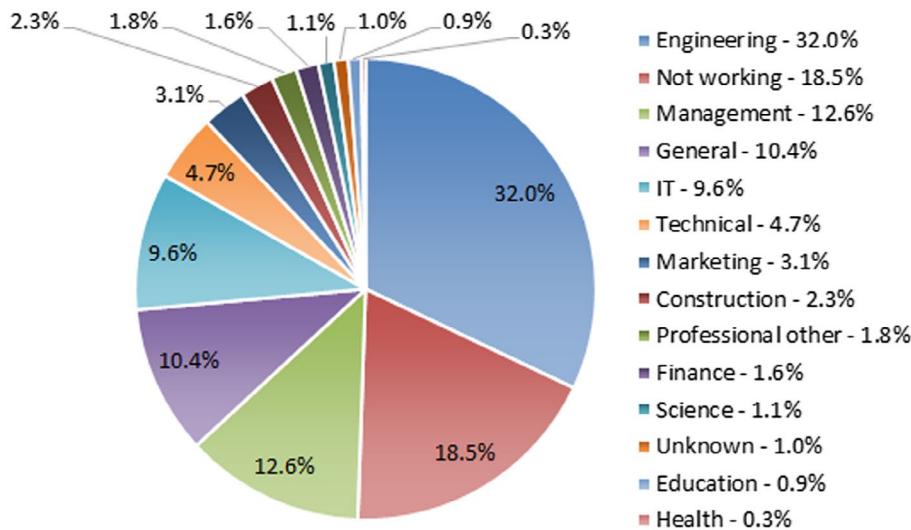


Figure 1. Proportions of occupational classifications of engineering bachelor graduates – based on the 2011 Australian census data.

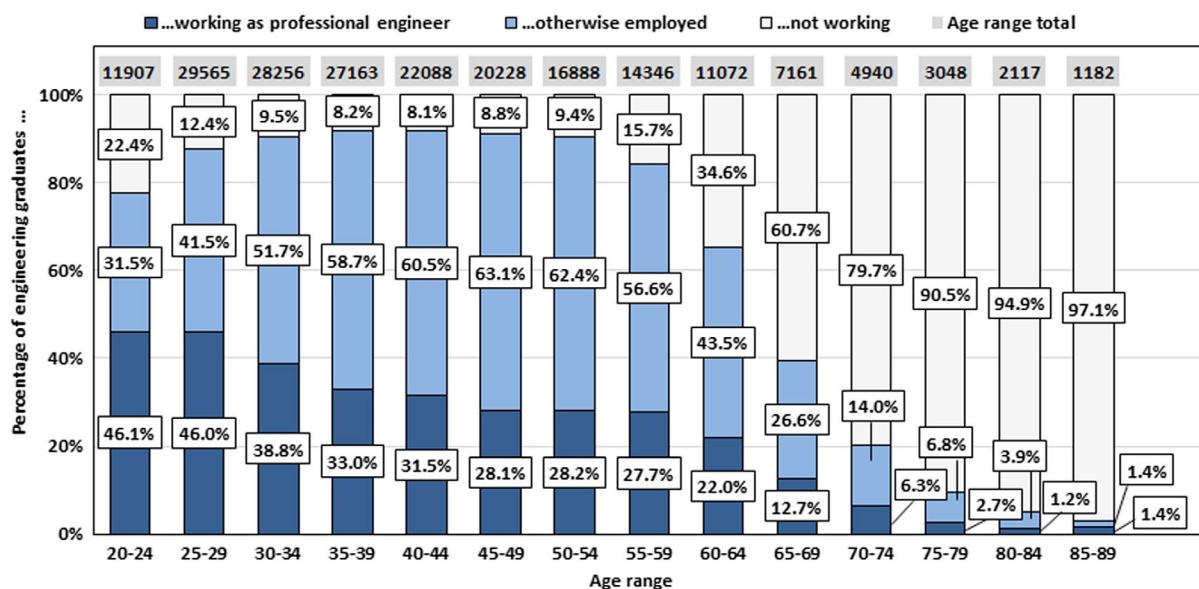


Figure 2. Employment status of engineering bachelor graduates in five-year age ranges – based on the 2011 Australian census data.

graduates, Choy and Bradburn (2008) found that, 10 years post-graduation, only about half of the engineering majors were still working in a related field. Using the Australian census data, Trevelyan and Tilli (2010) found that across the period 2001–2006, about half of all bachelor or higher engineering graduates aged 25–55 years were not working in engineering-related jobs. When census data for higher degree graduates was included in the data-set above, the total number of engineering graduates increased by about 25%, but the proportions in Figures (1 and 2) did not significantly change. The proportions presented in Figure 1 do not seem out of accord with similar investigations.

Regarding Figure 2, data on Australian higher education course completions (Department of Education and Training 2014) show 6237 domestic bachelor graduates in the field of ERT in 2010 (who were no longer an undergraduate at the time of the 2011 census). Given

that some of these graduates may have travelled overseas post-graduation, approximately 12,000 engineering bachelor graduates in the 20–24-year age range, and slightly less than 30,000 in the adjacent five-year age ranges in Figure 2 (representing periods when there were similar annual numbers of graduates) seems realistic. The 2010 course completions data above indicate that 75.0% of all 2010 Australian bachelor graduates were aged less than 25 years. Using Graduate Careers Australia (2012) data from the 2011 Graduate Destination Survey (GDS), nearly two-thirds of all 2010 Australian bachelor graduates were still aged under 25 years when surveyed four months after graduation in 2011. Specifically for engineering, the GDS reports that 21.5% of recent graduates surveyed were not working. Given that the majority of engineering bachelor graduates are likely to be aged less than 25 years, the GDS figure for 'graduates not working' matches well with the first column in Figure 2.

4.2. The leaky STEM pipeline 'problem'

Figure 1 indicates that approximately half of all engineering bachelor graduates are not working in engineering occupations, and as noted above, this is likely to be a systematic underestimate. Nearly 20% of the balance are not working, and overall, about one-third of all Australian engineering bachelor graduates reported working in an engineering occupation. Figure 2 shows how these proportions vary with graduate age. Even in the youngest age band, likely to include the majority of recent engineering bachelor graduates, the proportion working in an engineering role is less than half. This holds at around 46% for 5 years, then declines over the next 10 years to one-third or less and then slowly declines to about one in five at the typical retirement age. Nearly one-third of recent engineering graduates are working outside of engineering and within 10 years, this proportion exceeds 50% and does not fall below half until a significant number begin to retire. More than 20% of recent graduates are not working, although this rate has approximately halved within five years. This proportion reaches a minimum (of around 8%) through the age range 35–44 years, perhaps due to those with family commitments returning to the workforce and/or the entry of mature-age engineering graduates. Following age 55, the proportion not working increases significantly as people begin to retire.

The literature suggests that some graduate engineers are lured by financial rewards, or driven by personal interests, into other industrial sectors. There is also evidence of structural changes in engineering work, and work opportunities, that may contribute to engineering graduates working in non-engineering jobs. In the USA, Rothwell (2013) notes a steady increase in the proportion of all jobs requiring high STEM skills from around 7% in 1880 to around 20% in 2011, that these jobs can now be found in all sectors of the economy (not just in traditional STEM areas) and that engineering is the STEM discipline with the largest proportion of skills in demand. In the UK, Lyons (2011) differentiates between the STEM sector, the 'STEM skills' sector and the non-STEM sector, but notes that organisations in all of them may seek to employ STEM graduates.

Charette (2013) reports on dramatic changes in general engineering employment in the USA over recent decades. He notes that, rather than the prospect of a career with a company, many engineers are now employed on a project-by-project basis and may find that their employment ends with the project. Furthermore, continuing professional development previously offered by companies is now rarer, so an out-of-work engineer may find their skills out-of-date when seeking a new engineering job. Benderly (2015) quotes Sheri Sheppard of the US National Academy of Engineering; '... workers who leave fast-moving engineering fields but later want to return frequently find that difficult or impossible

because the field has moved on ... This particularly affects women who interrupt careers to raise children.' (Benderly 2015, 16).

As noted above, except in a limited range of statutory areas, practising as an 'engineer' is generally not legally restricted in Australia. However, membership of Engineers Australia is controlled, requiring possession of a recognised Australian or international undergraduate degree or a migration skills assessment for the Graduate grade of membership. Those seeking Chartered Professional Engineer (CPEng) status must meet a range of requirements on qualifications, practice experience and continuing professional development. It is possible that the hurdle requirements for CPEng are insurmountable for some, and are a catalyst for seeking career advancement in another field.

In a large investigation of the UK STEM graduates and employers, Mellors-Bourne, Connor, and Jackson (2011) questioned the assumption that all STEM students intend to pursue a career in STEM. They found only half of all final-year STEM students 'definitely' wanted a career in their study area, although this rose to about 63% for engineering students. A key finding was that many STEM students are not presuming a STEM career and that students' and graduates' career decision-making is highly fluid, with a significant proportion of students having no, or only vague, career plans, and that this was the cause of many of the individual non-STEM career paths observed for STEM graduates. In a survey of recent Australian engineering graduates in 2008, it was found that, 'Given the opportunity, most respondents would choose engineering studies again, however many were equivocal about staying in engineering in the medium to long-term.' (Department of Education Employment and Workplace Relations 2009, 24). Only 29% of respondents saw themselves remaining in engineering for 10 years or more, and nearly half the respondents indicated less than 10 years. One-quarter of respondents indicated 'uncertain' or gave no response – the report's authors speculated that this indicated that some graduates were keeping their options open, lending weight to the idea of recent engineering graduates having fluid views on their career. Benderly (2015) reports a similar figure of around 25% of new US engineering graduates considering careers outside of engineering.

The 2011 Australian census data support the idea that many, and within 10 years of graduation, a majority of, bachelor-qualified engineering graduates are working in a non-engineering role. Similar findings in the UK and USA generate a range of policy perspectives. Drawing on a number of sources, Charette (2013) views STEM graduates working out-of-field as a contributor to a contrived 'shortage' of STEM graduates in the USA, and that calls for more STEM graduates are self-servingly supported by the government being keen for an abundance of engineers and scientists to serve national innovation

and defence; by universities being keen to enrol more taxpayer-funded STEM students; and by industry being keen to avoid wage rises that would occur in a genuine shortage of STEM workers. Less cynically, but ultimately perhaps no more practically, Lyons (2011) quotes the head of Graduate Prospects (a commercial careers service owned by the UK universities) as saying, 'We need to make the careers that require STEM backgrounds much more attractive ... How can engineering firms compete against the salaries on offer at law and city firms?' (5)

Similarly, Bhattacharjee (2009) quotes the Director of the US Commission on Professionals in Science and Technology as suggesting that more STEM graduates would be retained if they thought that they could work on solving societal problems; 'Really good people will be less concerned about money if they can do work that is meaningful to them ...' (654). More pragmatically, Lyons (2011) quotes views from the 2010 UK Sector Skills Assessment for Science, Engineering and Manufacturing Technologies, 'Unfortunately we don't live in a command-and-control economy so we can't direct [STEM] graduates into [STEM] jobs' (5). Mellors-Bourne, Connor, and Jackson (2011) note that the premise that those studying STEM automatically progress to a STEM job has been a key element of the UK Government's STEM skills development strategy and that this view of the STEM pipeline requires rethinking. Government policy in this area is crucial as it sets national directions and funds programmes (note the significant budget resources typically involved – US\$2.9 Billion in 2015 in the USA (The Office of Science and Technology Policy 2014).

4.3. A broader conception of the purpose(s) of engineering education

Holt, Johnson, and Harrison (2011) pose two key questions for the UK policy-makers to consider: (i) 'Is the proportion of graduates with STEM degrees working in non-STEM occupations a problem?' and (ii) 'Is an over-supply of STEM graduates a problem?' (22). Higher education is expensive and a traditional economic response would be that a mismatch between academic training and occupational outcome is an inefficient use of resources that costs both the individual and society as a whole (Boudarbat and Chernoff 2012; Xu 2013). The Australian Department of Education Employment and Workplace Relations (2009) noted that the 'leaky pipeline' in engineering is often referred to in negative terms such as 'wastage' and 'attrition', based on a particular view of the purpose of higher education. However, they say:

An alternative view is that while the Australian Government invests in funded places for the purposes of building a prosperous society and economy, the means by which highly skilled graduates will achieve this are somewhat more diverse ... It may well be necessary for many of these graduates to explore options other than employment as an engineer in Australia on completion of their

degree. Several of these options still have the potential to deliver a range of benefits to the Australian society and economy over the longer term. ... Graduates working in related occupations will bring their engineering background with them, providing them with a multi-disciplinary outlook that has the potential to make them the flexible, open minded, highly skilled employees that many industries need to develop new business strategies (8–10)

There is support for this view in the USA as well:

Some workshop participants view movement of engineering students and workers into ... other occupations as 'leakage' from the engineering profession. Others consider it an appropriate and desirable use of widely applicable and effective abilities and knowledge ... Salzman ... thinks the flow of people across disciplines is 'the strength of U.S. higher education' and something the system should facilitate rather than 'encouraging lock-in at an early age ...' (Benderly 2015, 9–16)

As noted above, a Department of Education Employment and Workplace Relations (2009) survey of recent Australian engineering graduates found that those not working in an engineering occupation were nonetheless likely to be in a high-skill occupation. The additional tables accompanying the 2011 GDS (Graduate Careers Australia 2012) do not indicate precisely if recent graduates are working in the same field as their undergraduate study, but do indicate that 75.0% of surveyed engineering graduates who were working full-time indicated that their field of studies was 'important to' or 'a formal requirement of' (split about equally) their job. The same data source shows that 91.0% of engineering graduates working full-time indicated that they were in a professional, management or technical (i.e. high-level occupational) role – veterinary science was the only other broad field of education with a greater proportion of recent graduates working in high-level occupational roles.

STEM careers in general are subject to a 'curious mix of myths' regarding the relationship between undergraduate discipline and jobs, education qualifications and job security and expected wage progression, and these assumptions demand closer examination (Feller 2010). Rothwell (2013) notes that public policy debate about the STEM economy has been hindered by fuzzy definitions of what is STEM knowledge and employment, binary classifications of jobs as STEM or non-STEM that ignores variation in STEM knowledge requirements and other assumptions about STEM employment. While perceptions of a general 'shortage' of STEM workers in some developed economies might be warranted (Carnevale, Smith, and Melton 2011; Lyons 2011), more careful examination often reveals wide variation in worker shortage/surplus between disciplines and sectors. In a detailed study of the US STEM labour market, Xue (2014) concluded, 'Across all the different disciplines, yes, there is a "STEM Crisis and no, there is not a "STEM Crisis". It depends on where you look" (49). Specifically for engineering, Benderly (2015) observed that graduates can expect good, but not great, pay and job security, good job satisfaction, relatively slow career advancement and careers options outside of engineering, and women in engineering will find themselves in a small minority.

She sums this up as, ‘... engineering as a career is a lot more complicated’ (Benderly 2015, 3). In Australia, the 2011 GDS data on graduate employment revealed widely varying levels of full-time employment between engineering disciplines (i.e. 97.3% for mining engineering and 71.7% for chemical engineering) and in other STEM discipline areas (i.e. 61.5% for life sciences and 77.8% for computer science) (Graduate Careers Australia 2012).

5. Key findings and conclusions

The finding that, even immediately post-graduation, a significant proportion of engineering bachelor graduates do not work in engineering roles has implications for undergraduate engineering education. As Xu (2013) notes (citing Roksa and Levey), ‘finding a job in one’s fields of study is not only an individual dilemma, it is a process that reflects the relationship (or the lack thereof) between the educational system and the labor market’ (378). Mellors-Bourne, Connor, and Jackson (2011) observe that, in the UK secondary education, the ‘broadening’ career benefit of studying STEM subjects is recognised in policy and the full range of jobs open to STEM graduates, both in the STEM and non-STEM sectors, should be more widely acknowledged in higher education and should be a key element of careers advice provided to students prior to higher and further education. Searching for information regarding where graduates might work in promotional materials for engineering programmes is far more likely to reveal descriptions of automotive manufacturing, bridge construction, power generation and water treatment than it is to show teaching calculus, completing foreign exchange transactions, authoring user manuals and selling medical electronic equipment, though both sets of outcomes are probably equally likely. Benderly (2015) reports on the announcement of a 2015/16 US National Academy of Engineering study on career pathways that:

... will assess ‘the expectations, training, employment options, and employment choices of those trained or employed as engineers in the United States,’ and thus ‘broaden the thinking of engineering educators, employers, and policy-makers about the connections between engineering education and the workforce.’ ... The study calls for a demographic and educational analysis of the people who work as engineers and those with engineering training who do other kinds of work, and the implications of their decisions and career pathways for engineering education at all levels. (Benderly 2015, 3)

It is apparent that the existing models of engineering education actually suit many employers, both STEM and non-STEM, and wholesale curriculum change is likely to be a disproportionate response to acknowledging the full spectrum of engineering careers beyond the traditional confines of the profession – to employ the apocryphal engineering maxim, ‘if it ain’t broke, don’t fix it’. Trevelyan and Tilli (2010), in response to analysing 2001 and 2006 Australian census data and finding that international students who studied engineering in

Australia had a significantly lower chance of working in engineering compared to Australian-born students, recommended that international students be given an honest appraisal of their career prospects. While we don’t specifically address student nationality issues here, it is possible that work visa requirements play a part in the occupational choices that some international engineering graduates make post-graduation. We conclude that ALL engineering students would be better informed about, and equipped for, the world of post-graduation work if they were exposed to the likely options for their career trajectory, as confirmed by this research. Likewise, secondary school students and others considering engineering undergraduate study would be more honestly advised if they were informed about the full range of career possibilities for engineering graduates and the probability that they are just as likely to work out of engineering as in it. As Mellors-Bourne, Connor, and Jackson (2011) note, in the UK, the broad career options open to STEM graduates are viewed as a positive benefit in promoting STEM careers to secondary school students.

An additional UK perspective on undergraduate education and career choice is that many STEM graduates enter non-STEM careers because of lack of experience of what work in the STEM field might entail in practice (Mellors-Bourne, Connor, and Jackson 2011). They also report on research that indicates that degree-related work experience had a strong positive influence on STEM students’ career intentions towards STEM. For the UK engineering students, Atkinson and Pennington (2012) note that engineering work experience is strongly related to graduate employment and is highly valued by engineering employers. They recommend work experience to undergraduate engineering students both for the professional learning that it offers and for connecting with potential employers. In Australia, 12 weeks of engineering-related work experience (or a satisfactory alternative) is recommended by Engineers Australia as a requirement for graduation. Drawing on the research presented here, perhaps the most progressive conception of engineering work integrated learning (including relevant learning objectives, student preparation and summative assessment) is one that caters for relevant non-engineering professional work experience, entrepreneurial-/start-up-style new business development student projects, as well as placements in more traditional engineering workplaces.

Trevelyan and Tilli (2010) note that the engineering school advisory boards that provide input to course curricula (and other matters) are typically comprised of representatives from traditional engineering industries. We find that such advisory board representatives can provide an authentic view of employer requirements for about half of the graduates of a typical Australian undergraduate engineering programme. We support the



call by Trevelyan and Tilli (2010) for engineering schools to reconsider the employer stakeholder representation on their advisory boards in light of the full range of the likely career destinations of their graduates.

There is a range of additional investigation that could be undertaken to extend the research presented here. 2016 is the year in which the next Australian census is scheduled and the data eventually available from that collection could be interrogated to confirm the findings from 2001 to 2006 by Trevelyan and Tilli (2010) and for 2011 as presented here. As noted by Charette (2013), the STEM workforce of a nation is much bigger than just bachelor graduates, incorporating graduates with technical certificates, associate degrees, master degrees and PhDs, as well as non-STEM graduates working in the STEM sector. The analysis presented here looks only at bachelor's degree holders and could be extended to consider the career outcomes for other engineering-related qualifications. Trevelyan and Tilli (2010) note different engineering career outcomes for international students compared to those born in Australia. Other research notes different career outcomes for female students in STEM, generally, (Anlezark et al. 2008) and in engineering, specifically (Litzler, Lange, and Brainard 2005). The analysis presented here considers all graduates together – the census data provide access to a range of demographic variables that would permit more fine-grained/differential analyses to be performed. There is also evidence internationally that geography has a strong influence on STEM career opportunities (Holt, Johnson, and Harrison 2011; Mellors-Bourne, Connor, and Jackson 2011; Rothwell 2013), and specifically for engineering in Australia (Department of Education Employment and Workplace Relations 2009) – it would be valuable to better understand the impact of geography on Australian engineering career trajectories.

Trevelyan and Tilli (2010) call for more work to, 'understand why graduates either choose not to or are unsuccessful in finding work in the engineering industry' (114). In relation to STEM more generally, Mellors-Bourne, Connor, and Jackson (2011) go further in identifying, 'the need to strengthen evidence on the "career journey"' (42). Engineering schools should cultivate strong ongoing links with all of their alumni, regardless of their employment status and the sector that they work in, so as to better understand the career outcomes of their graduates and hence to better prepare their future graduates for the world of work, whatever path they follow. Finally, we have documented a method of analysing the relationship between educational qualifications and occupational outcomes using the Australian census data. This approach is likely to also yield valuable information for those involved in the education of other professional and occupational groups in Australia.

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